UM0497
User manual

USB Li-Ion battery charger evaluation board

Introduction

This document explains the functioning of the USB-based single cell Li-Ion battery charger evaluation board which consists of a ST7260E2-based low-speed USB controller and a battery charger based on the ST7LIT15BY0.

The evaluation board includes a power selector circuit to select the appropriate power supply source and a step-up converter circuit based on the L6920 device to provide a fixed output voltage to the USB controller. The power supply for the battery charger controller is generated from the TL1431programmable voltage reference, keeping in mind the accuracy requirement for charging. An additional current limiter is also included in series with a USB power supply to show any incorrect behavior using a status LED.

A provision is provided on evaluation board such that any external low-speed USB controller can control the operation of the charger, hence this system can be used with any low-speed USB controller.

The charger used in the board utilizes a modified form of non-inverting buck-boost converter to support the charging voltage requirement for single cell Li-Ion battery. This converter is explained in more detail in AN2390.

This evaluation board represents a complete USB-based portable battery charging system for a single cell Li-Ion battery, such as those used in MP3 players.

There are separate ICP connectors provided on the board to reprogram the USB controller and charger controller.

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1 Getting started

1.1 Package contents

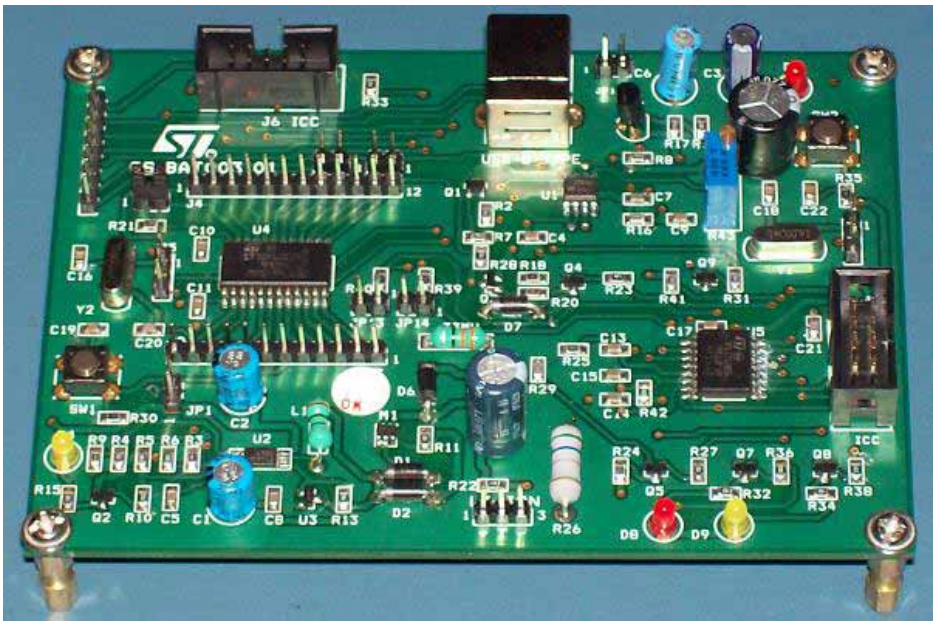
The USB Li-Ion battery charger evaluation board includes the following items:

- Hardware content:
  - One evaluation board
- Documentation:
  - User manual

1.2 Hardware description

Figure 1 below shows the snapshot of the evaluation board.

Figure 1. USB Li-Ion evaluation board (STEVAL-ISB003V1)



1.2.1 Power supply

The evaluation board is powered by a USB bus directly. As only 100 mA current is available by default from the USB bus, the charger is inititally kept in shutdown mode. After proper enumeration is done by the USB controller to increase the supply current limit to 500 mA, the charger switches to ON to start charging the battery.

1.2.2 Current limiter (ST890B)

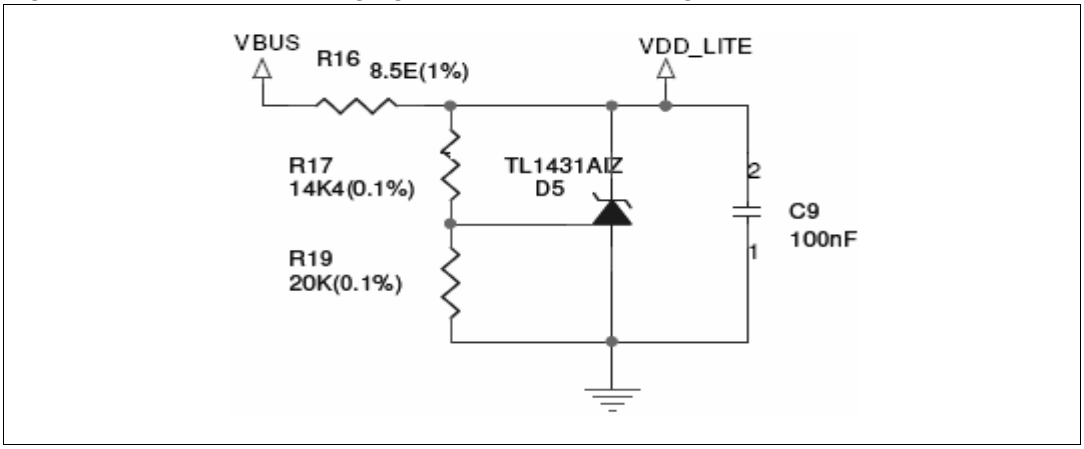
To provide additional information about the USB supply current, a current limiter (ST890B) is kept in series of the USB supply. There is a STATUS LED (D3) connected with the FAULT pin of this current limiter.

This LED glows HIGH whenever the supply current increases from 500 mA. In the evaluation board, the current limiter is used only to show the status of whether the current limit is crossed or not, but it is not used to cut off the power supply.

1.2.3 Precision supply for the charger

Figure 2 shows circuit for the precision supply for the charger system. Here TL1431AI, which provides 0.25% accurate reference voltage, is used to generate a precise voltage supply for the charger system.

Figure 2. Reference voltage generation for the charger

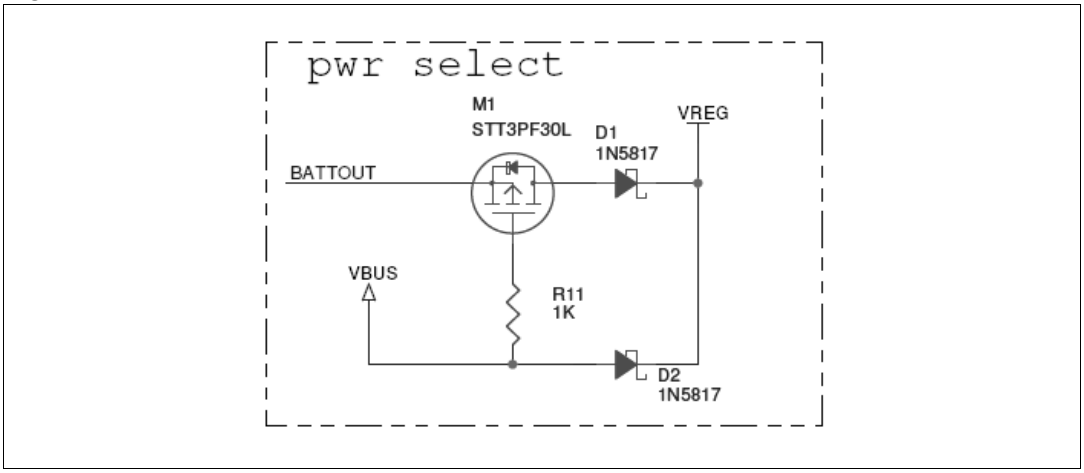


With the help of this precision supply, we can easily achieve the 1% accuracy target which is mandatory for Li-Ion charger systems.

1.2.4 Preferential power selector circuit

Figure 3 shows a preferential power selector circuit which is used to select the source power supply for the USB controller.

Figure 3. Power selector circuit

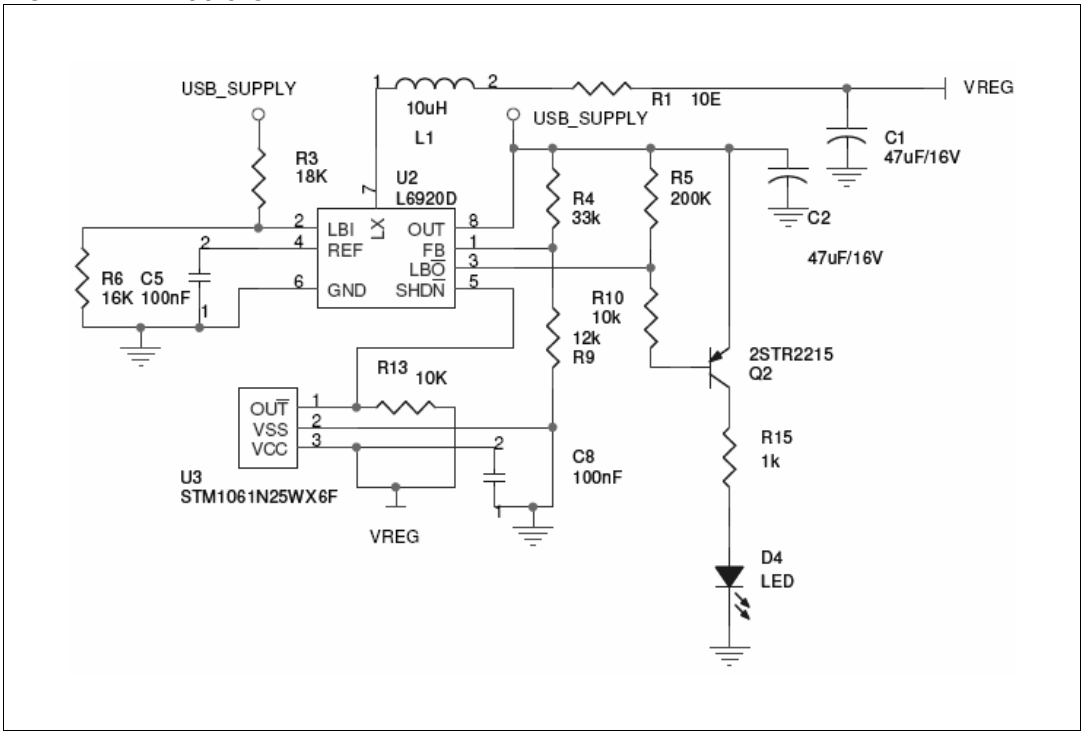


This selector circuit works as follows. Whenever the USB supply (VBUS) is available, it is used as the source supply. Battery power is only used when the USB supply is not available.

1.2.5 Supply generation circuit for the USB controller

Figure 4 shows L6920-based supply generation circuit for the USB controller. USB_SUPPLY is the output voltage and VREG (output voltage of the power selector circuit as in *Section 1.2.4*) is the input voltage of this circuit. The output voltage USB_SUPPLY is programmable. In the evaluation board it is set at 4.5 voltage and depends on the ratio R4/R9. Please refer to the L6920 datasheet for more details.

Figure 4. Supply generation circuit for the USB controller



LED (D4) is used to show the status of the input supply availability which glows whenever the input supply falls below a certain threshold (determined by the voltage at LBI).

1.2.6 Supply shutdown control circuit for the USB controller

The STM1061 as shown in *Figure 4* is used to control the shutdown operation of the L6920. It puts the L6920 in shutdown mode whenever the input supply voltage falls below 2.5 V.

1.2.7 Jumpers and connectors

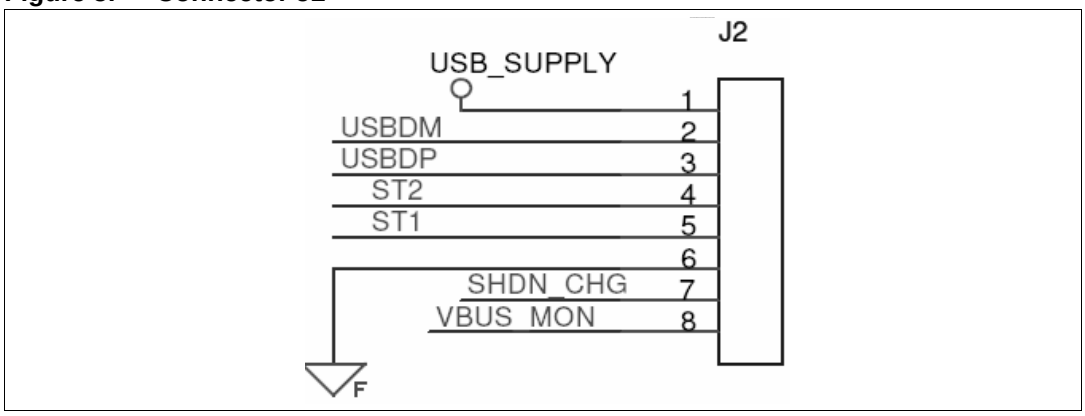
The following important jumpers control the operation of the evaluation board and are explained according to their applications:

J2, JP1, JP3, JP12, JP13, JP14 and JP16 are used to select between the USB controller available on the evaluation board and the external USB controller.

The role of each individual jumpers is as follows:

- JP1: to connect USB_SUPPLY to the V_{DD} pin of the USB controller
- JP3: to connect USBVCC to USBDM through a 1.5 kΩ resistor.
- JP12: to monitor the availability of the VBUS signal.
- JP15: to connect to the SHDN_CHG pin of the charger. This is used to put the charger in shutdown mode until proper enumeration is done.
- JP13, JP14: These are used to connect to the status pin
- JP16: to connect the USB supply pin to the demonstration board supply pin. Pin 1 of this jumper is the USB supply pin (USB_V_{DD}) and pin 2 is the demonstration supply pin (VBUS). For the standalone charger, please connect the external supply to pin 2 of JP16.
- J2: As shown in *Figure 5*, this is a 7-pin connector and can be used to connect to the external USB controller.

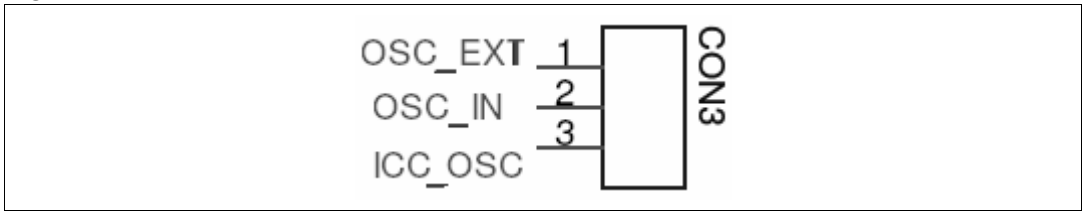
Figure 5. Connector J2



Warning: You can connect to only one USB controller at a time. If you want to use an external USB controller, you must open all the jumpers (JP1, JP3, JP12, JP13, JP14 and JP15) required by the USB controller.

J5 and J7: These are 3-pin connectors and are used to select between the ICC clock and resonator clock. J5 is used for selecting the clock source for the USB controller (ST7260E2) available in the evaluation board and J7 is used to select the clock source of the charger IC (ST7LIT15BY0). As shown in *Figure 6*, if we short pin 1 and 2 then the external resonator is used as the clock source and if we short pin 2 and pin 3, ICC clock is used as the clock source. In general we short pin 1 and pin 2.

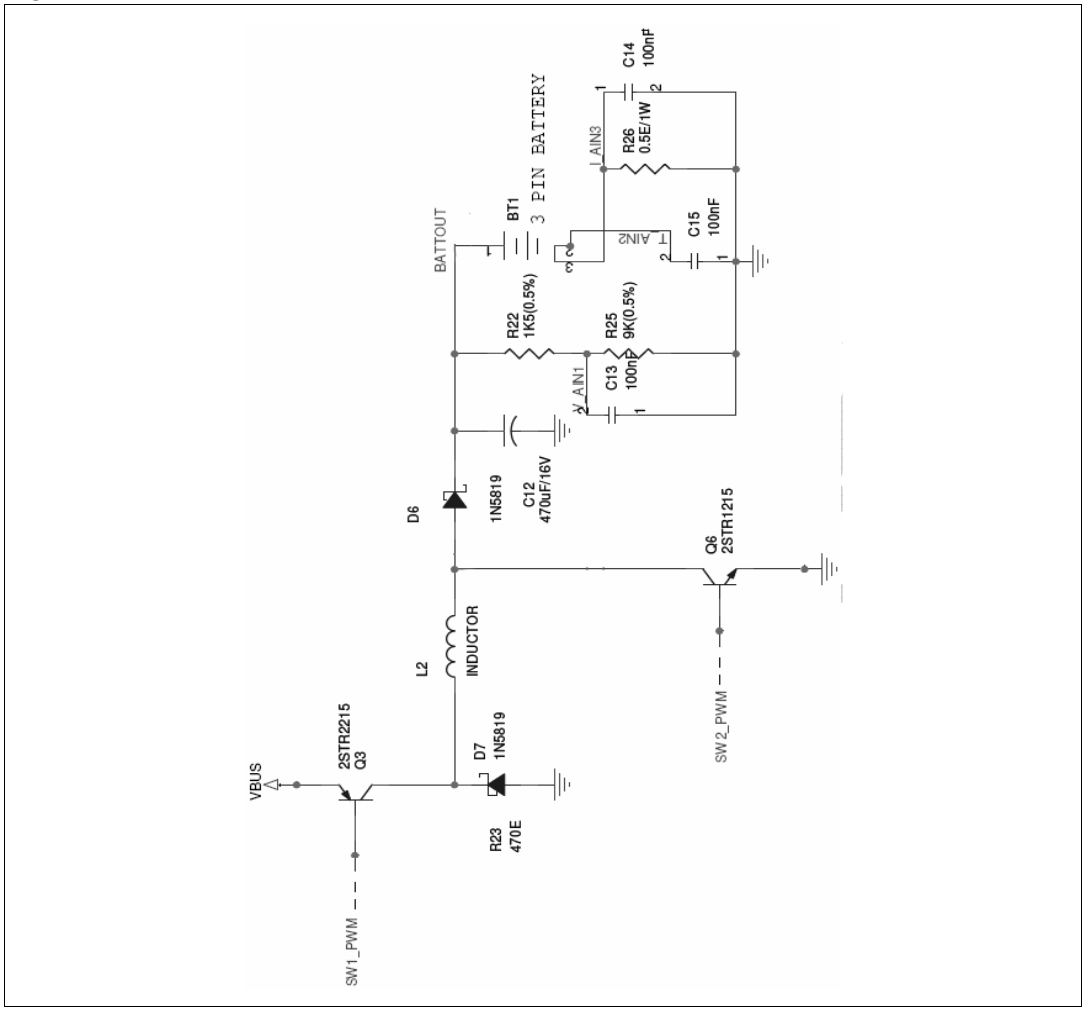
Figure 6. Clock selector



1.2.8 DC-DC converter circuit

Figure 7 shows the circuit diagram of the DC-DC converter circuit which is controlled by the two PWM signals coming from the charger controller ST7LIT15BY0.

Figure 7. DC-DC converter circuit



This DC-DC converter provides power to the single cell Li-Ion (3-pin battery pack) based on the battery voltage, current and temperature measurements. Please refer to AN2390 for more details regarding this DC-DC converter circuit.

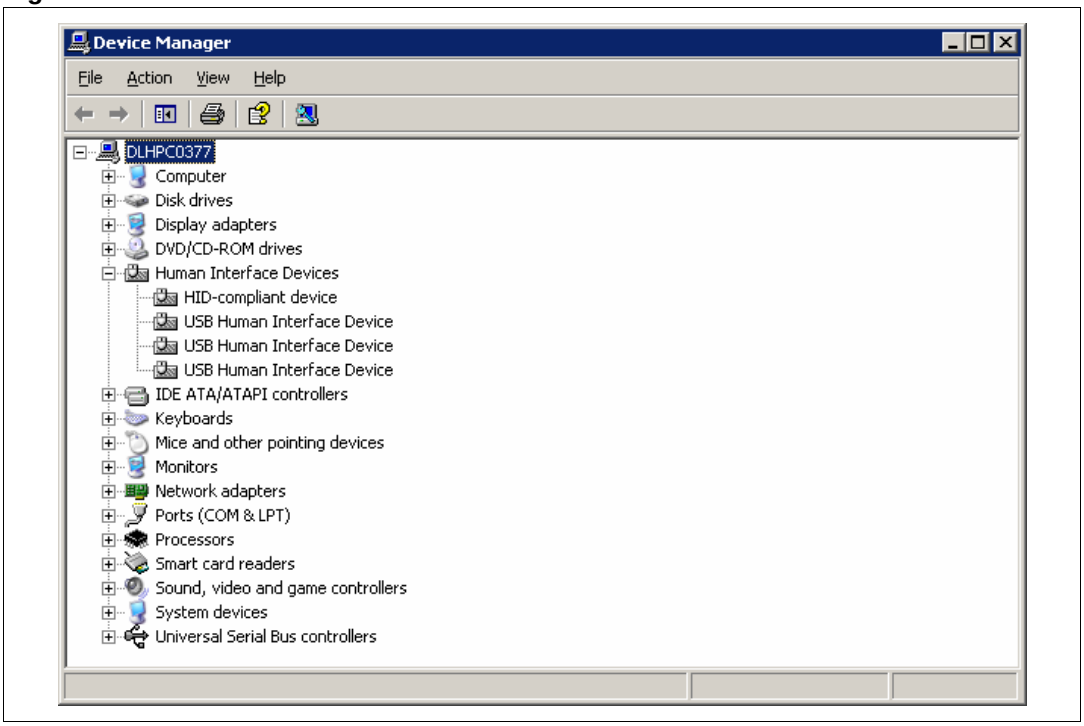
2 Running the evaluation board

After ensuring that all the jumpers are connected correctly as explained in the previous section, the evaluation board is ready to be used.

2.1 Connecting to the PC

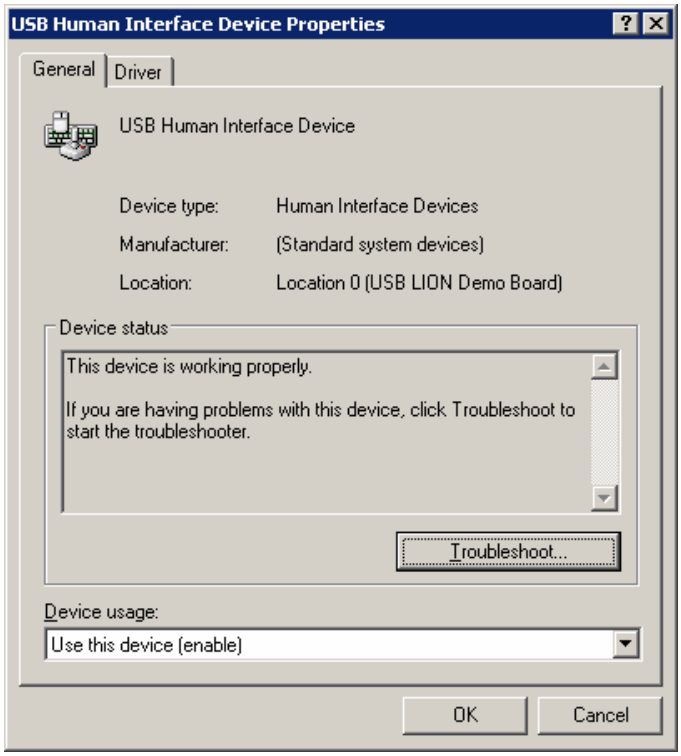
As soon as you connect the USB connector to the evaluation board, you should find the evaluation board enumerated as an HID device as shown *Figure 8*.

Figure 8. Enumeration result



And if you check the properties of all these HID devices, you should find the property of one HID device as shown in *Figure 9*.

Figure 9. USB Li-Ion evaluation board HID

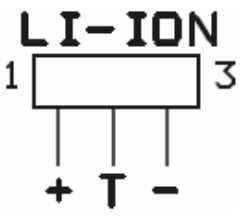


This ensures that the evaluation board is connected properly to the USB and now ready to be used. Now we can proceed to the next steps.

2.2 Connecting the Li-Ion battery

The evaluation board is not provided with any specific slot in order to avoid making it package specific. Instead a 3-pin connector is provided on the evaluation board as shown in *Figure 10*.

Figure 10. Li-Ion battery 3-pin connector



You can either solder a particular slot to this connector and then connect the battery in that slot, or if you are directly connecting the battery to the connector, please ensure that the battery is properly connected as improper connection may affect the accuracy of the analog measurement, thus affecting the overall accuracy of the charging.

2.3 Battery charging status monitoring

There are two LEDS available (D8 and D9) on the evaluation board. *Table 1* explains the behavior of these status LEDs according to the charging status.

Table 1. Charging LED status

SL NO	Charging status	Red LED (D8)	Green LED (D9)
1	Battery not present / Idle	OFF	OFF
2	Charging ongoing	ON	OFF
3	Charging done	OFF	ON
4	Error in charging	ON	ON

Note: An error condition occurs for following reasons:

Temperature (heat or cold condition)

Short-circuit

Bad battery when the impedance of the battery becomes very low.

Note: For the condition due to a bad battery, if impedance of the battery becomes very high, then current does not flow through the battery. In this case charging is stopped and the status LED shows that charging is done.

2.4 Controlling/changing the charging parameters

The variables in*Table 2* are used to control different charging parameters.

Table 2. Controlling/ changing the charging parameters

File name: Bc.h				
Sl No	**Parameter name**	**Function**	**Formulae**	**Comments**
1	LION_VF_H	To define constant voltage threshold to fix the constant voltage level.	$X = \left[\left(\frac{threshold}{\{2 \cdot 3.6\}}\right)\right] \cdot 1024$	For example: X = 597 for 4.2 V threshold.
2	LION_VFAST	Voltage to switch from pre-charge level	$X = \left[\left(\frac{threshold}{\{2 \cdot 3.6\}}\right)\right] \cdot 1024$	For example: X = 469 for 3.3V pre-charge threshold.
3	LION_VFAIL	Not used		
4	LION_VF_L	Not used		
5	LION_VSC	Used along with LION_TFAIL to define bad battery condition	$X = \left[\left(\frac{threshold}{\{2 \cdot 3.6\}}\right)\right] \cdot 1024$	For example: X = 213 for 1.5V threshold.
6	LION_VSAT	Voltage to switch from pre-charge level	$X = \left[\left(\frac{threshold}{\{2 \cdot 3.6\}}\right)\right] \cdot 1024$	For example: X = 469 for 3.3V pre-charge threshold.

Table 2. Controlling/ changing the charging parameters (continued)

File name: Bc.h				
7	LION_ICONST	Current level during constant current charging	$Y = \frac{CurrentThre}{2.5}$	For example: Y = 120 for 300 mA charging current.
8	LION_ITRI_1	Constant current level during pre-charging phase	$Y = \frac{CurrentThre}{2.5}$	For example: Y = 20 for 50 mA pre-charging current.
9	LION_ITRI_2	Not used		
10	LION_IFAIL	Short-circuit current threshold	$Y = \frac{CurrentThre}{2.5}$	For example: Y = 140 for 350 mA short circuit current.
11	LION_ISAT	Current threshold to end charging	$Y = \frac{CurrentThre}{2.5}$	For example: Y = 18 for 45 mA short circuit current.
12	LION_VHEAT_UP	Heat indicator threshold	$Z = \left\{\frac{R1}{(10k\Omega + R1)}\right\}256$	For example: Z = 80 for 45 Celsius degree temperature (Here R1 is in kΩ).
13	LION_VHEAT_DOWN	Cold indicator threshold	$Z = \left\{\frac{R1}{(10k\Omega + R1)}\right\}256$	For example: Z = 195 for 0 Celsius degree temperature (Here R1 is in kΩ).
14	LION_TFAIL	Used with LION_VSC		
15	LION_TEXP	Expiration in minutes	$W = \frac{(\text{expected time expiration value in minutes})}{2}$	For example: W = 150 for a 5-hour time expiration.

3 Using the external USB controller

Before using the external USB controller, you must remove all jumpers (JP1, JP3, JP12, JP13, JP14 and JP15). After that you need to do the connections as mentioned in *Section 1.2.7*. To use the external USB controller in order to control the charging operation, you must do the following steps:

1. First disable the SHDN_CHG pin by making it low to switch off the charger.
2. Do the proper enumeration of the USB cell to increase the current limit up to 500 mA.
3. During battery charging, as the USB controller is also being powered by a USB, the power consumption of the system should be kept at less than 150 mA, otherwise we may not achieve the targeted 250 mA charging current.
4. After completing steps 1, 2 and 3, enable the SHDN_CHG pin to high to enable charging operation.
5. Connect the battery.
6. Start monitoring the status of the battery charging by monitoring the status pin ST1 and ST2. Using these status pins, you can control the activity of the external USB controller to minimize the current consumption while the battery is being charged.
7. Disable the SHDN_CHG pin again by making it low to reduce any consumption by the charger.
8. Follow steps 1 to 7 to charge another battery.

4 Using the charger in standalone mode

You can use the charger available in this evaluation board in standalone mode as well. In standalone, it provides an option of developing a low-cost battery charger which is capable of charging a single cell Li-ion battery from a 5 V power supply.

To use this evaluation board in standalone mode, do the following steps:

1. Select the external power supply (5 V, 1 A) by connecting the positive pin of this supply to pin 2 of jumper JP16 (see *Section 1.2.7*) and the negative pin to ground (see *Figure 11: Schematic*).
2. Remove jumpers JP1, JP3, JP12, JP13, JP14 and JP15 to isolate the USB controller.
3. Connect the SHDN_CHG pin (pin 2 of JP15) to VBUS (pin 2 of JP16) to enable the charger operation (see *Figure 11: Schematic*).

The charger is now enabled and ready to be used in standalone mode.

If you connect the battery as mentioned in *Section 2.2*, then its presence is detected within a few seconds and the charging operation starts.

Again as mentioned in *Section 2.3*, LED8 and LED9 are used to show the charging status.

5 Warning/limitation

The limitations/warnings in using this evaluation board are as follows:

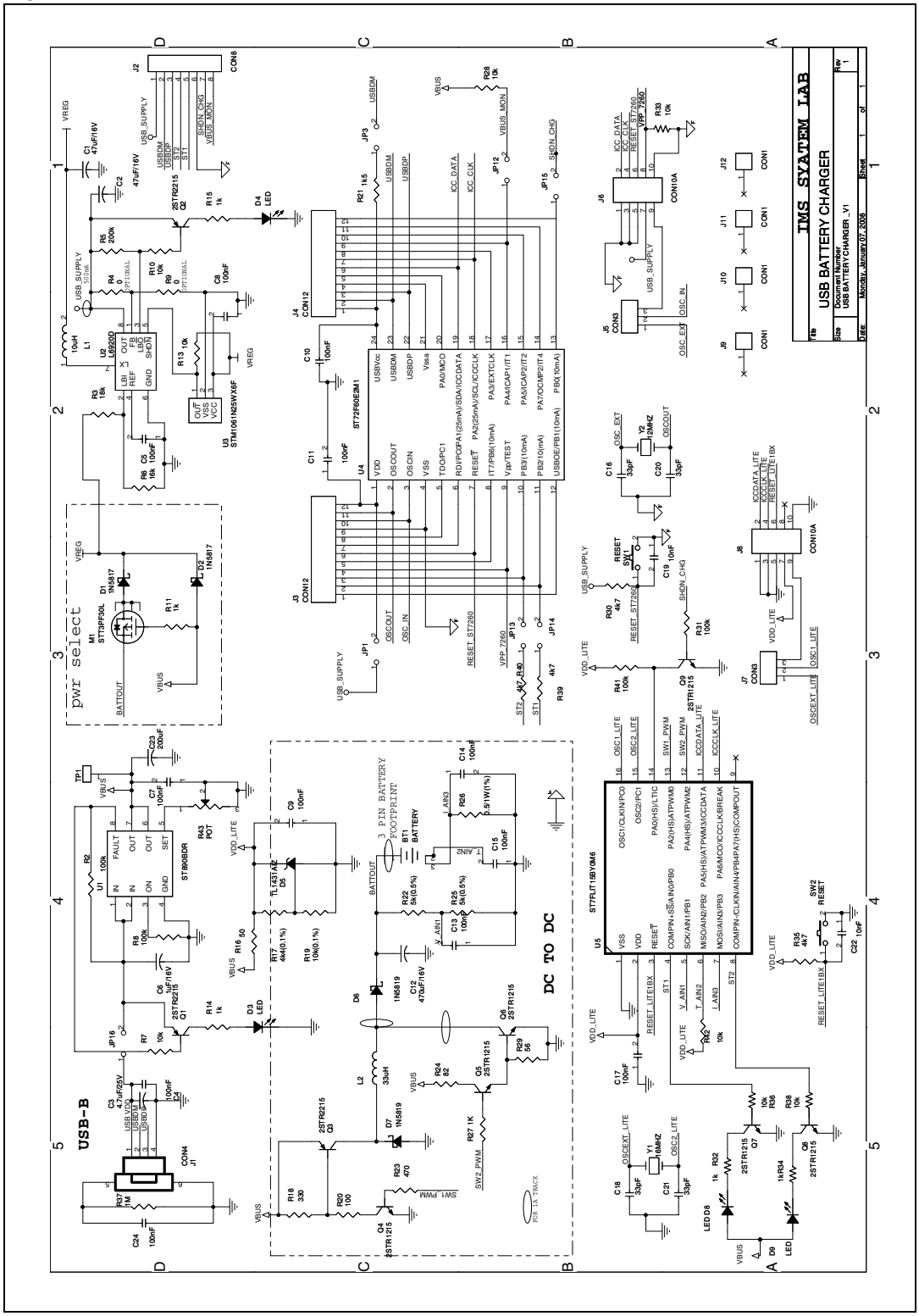
1. The charging current is limited to 300 mA value using the USB supply. You can use an external supply for increasing the charging current by using it in standalone mode as mentioned in *Section 4*.
2. There is no protection for reverse battery polarity connection, but it can be provided according to customer requirements.

6 Reference

1. AN2390: A Flexible Universal Battery Charger.

Appendix A Schematic

Figure 11. Schematic



6.1 USB battery charger BOM

Table 3. Bill of materials

Index	Qty	Reference	Value/generic part number	Package	Manufact.	Manufacturer's ordering code/ orderable part number	Suppl.	Supplier's ordering code
1	2	C1,C2	47 µF/16 V	Electrolytic cylindrical	Any			
2	1	C3	4.7 µF/25 V	Electrolytic cylindrical	Any			
3	12	C4,C5,C7, C8,C9,C10,C11,C13,C14,C15,C17,C24	100 nF	805	Any			
4	1	C6	1 µF/16 V	Electrolytic cylindrical				
5	1	C12	470 µF/16 V	Electrolytic cylindrical	Any			
6	4	C16,C18, C20,C21	33 pF	805	Any			
7	2	C19,C22	10 nF	805	Any			
8	1	C23	200 µF	Electrolytic cylindrical	Any			
9	2	D1,D2	1N5817	DO41	ST	1N5817		
10	4	D3,D4,D8, D9	LED	Axial LED	Any			
11	1	D5	TL1431AIZ	TO-92	ST	TL1431AIZ		
12	2	D6,D7	1N5819	DO41	ST	1N5819		
13	7	JP1,JP3, JP12, JP13, JP14, JP15, JP16	Jumper	SIP-2	Any			
14	1	J1	CON4	SIP-4	Any			
15	1	J2	CON8	SIP-8	Any			
16	2	J3,J4	CON12	SIP-12	Any			
17	2	J5,J7	CON3	SIP-3	Any			
18	2	J6,J8	CON10A	Box header	Any			
19	4	J9,J10, J11, J12	CON1	Mounting holes	Any			

Table 3. Bill of materials (continued)

Index	Qty	Reference	Value/generic part number	Package	Manufact.	Manufacturer's ordering code/ orderable part number	Suppl.	Supplier's ordering code
20	1	L1	10 µH	Axial inductor	Any			
21	1	L2	33 µH	Axial inductor	Any			
22	1	M1	STT3PF30L	SOT23-6L	ST	STT3PF30L		
23	3	Q1,Q2,Q3	2STR2215	SOT-23	ST	2STR2215		
24	6	Q4,Q5,Q6 ,Q7,Q8, Q9	2STR1215	SOT-24	ST	2STR1215		
25	4	R2,R8, R31,R41	100 kΩ	805	Any			
26	1	R3	18 kΩ	805	Any			
27	2	R4,R9	0 (optional)	805	Any			
28	1	R5	200 kΩ	805	Any			
29	1	R6	16 kΩ	805	Any			
30	8	R7,R10, R13,R28, R33,R36, R38,R42	10 kΩ	805	Any			
31	6	R11,R14, R15,R27, R32,R34	1 kΩ	805	Any			
32	1	R16	50	805	Any			
33	1	R17	4k4(0.1%)	805	RS Components	215-3112		
34	1	R18	330	805	Any			
35	1	R19	10 kΩ (0.1%)	805	RS Components	215-3493		
36	1	R20	100	805	Any			
37	1	R21	1k5	805	Any			
38	2	R22,R25	5 kΩ (0.5%)	805	RS Components	215-3162		
39	1	R23	470	805	Any			
40	1	R24	82	805	Any			
41	1	R26	0.5/1 W(1%)	RES Axial	Vishay	CPF1R500000FL		
42	1	R29	56	805	Any			
43	4	R30,R35, R39,R40	4k7	805	Any			

Table 3. Bill of materials (continued)

Index	Qty	Reference	Value/generic part number	Package	Manufact.	Manufacturer's ordering code/ orderable part number	Suppl.	Supplier's ordering code
44	1	R37	1M	805	Any			
45	1	R43	POT	Top notch 3296	Any			
46	2	SW1,SW2	Reset	Push button	Any			
47	1	TP1	Test point	Single berg pin	Any			
48	1	U1	ST890BDR	SO-8	ST	ST890BDR		
49	1	U2	L6920D	TSSOP8	ST	L6920D		
50	1	U3	STM1061N25WX6F	SOT23-3	ST	STM1061N25WX6F		
51	1	U4	ST72F60E2M1	SO24	ST	ST72F60E2M1		
52	1	U5	ST7FLIT15BY0M6	SO16	ST	ST7FLIT15BY0M6		
53	1	Y1	16 MHz	Crystal oscillator	Any			
54	1	Y2	12 MHz	Crystal oscillator	Any			

7 Revision history

Table 4. Document revision history

Date	Revision	Changes
07-Feb-2008	1	Initial release

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